

N88-17620

LANGLEY 22/10/87

WINDSHEAR WARNING
AEROSPATIALE APPROACH

JL BONAPE

1. SUMMARY

Although our A300, A310, A300/600 are yet automatically windshear protected by the α floor system AEROSPATIALE has on study windshear warning system according to AC 25 XX and AC 120 XX.

All the numerical values used here after have not the mathematical rigour related to an exact science, they just allow us setting targets. They are milestones, they also lead to marks welcomed in our design process.

We set up targets, conservative as far as possible, and check using marks the good behaviour of the system.

We keep in mind at every moment that : the more confident the crew will be, the more flying safety will be improved.

The following paper is concerned by future onboard windshear warning system and the AEROSPATIALE approach.

2. MILESTONES : LOW ALTITUDE WINDSHEAR PROBABILITY

Several reports or study sponsored by the US Administration (NASA, FAA), Nimrod and Jaws projects, Professor T. FUJITA publications etc, makes the windshear phenomenon more comprehensive.

Some parts of the world seem to be more sensitive. They are generally situated between the two 40 th parallels and more particularly in the continental areas.

Europe seems to be free of windshears. But, in France, we observed strong shears near by the mediterranean sea (MARSEILLE, MONTPELLIER, PERPIGNAN TOULOUSE).

All those interesting remarks cannot help us in determining an occurrence probability for a low altitude windshear.

(Slide 1) Fortunately the amount of accidents or incidents observed over a 20 years period is low, nevertheless it allows us in defining a maximum milestone in a sensitive region of the world.

3. THE MARKS : WIND MODELS

Setting up our windshear warning systems we are supported by :

3.1. Accidents, incidents wind analysis mainly issued from BOEING studies, also called historical gradients (slide 2).

Their probability are such defined.

3.2. The AC 12041 (slide 3) whose probability is unknown.

3.3. The windshear training aid wind models whose probability is also unknown.

3.4. Some three-dimensional downburst models one can fit in size and intensity. Their occurrence probability are obviously unknown.

We will try to estimate the model's probability matching them with historical gradients.

To do so, we use the severity factor (slide 4) called "SF".

Using "SF" we define the weight of the shears for taking off historical gradients (slide 5) and for landing (slide 6).

Using the same observer we weight the windfields (slides 7, 8, and 9).

We can so appreciate whatever the wind modelization is.

Now we can compare the "SF" and balance the windfields versus the historical gradients (slide 10).

The same "SF" weighting can be used for windshear training aid wind models (slide 11).

Those weightings lead to the general comparison (slide 12) between historical gradients, windfields and wind models.

The comparison slides 12 and 10 comes from a visual analysis but two observers can help us in the comparison process : "WSF" and "PSF" (slide 13).

4. THE TARGETS - AEROSPATIALE WS WARNING SYSTEM

Considering our in flight experience, and the AC 25 XX and AC 120 XX demands we set the following targets (slide 14).

4.1. Performance

We have to detect the shears whose probability is equal or lower than 1.10^{-6} . If the system does not detect such gradient we have to show that the aircraft can take off or land safely within the common safety rules.

4.2. Nuisances

Nuisance can have several origins nevertheless none of them could occur with probability greater than 10^{-4} . Taking in account pilot training or protection of sensible areas by ground aids (LLAWS) we relax active or latent failures probabilities in accordance with AC 25 XX advices.

On the other hand, in the case of nuisance performance warning we cannot tolerate a warning rate 100 times or 1000 times greater than it could really exist.

So, as we did in the past with α floor system, we are developing for the future a windshear warning as credible as possible for crews, mainly in the most critical part of the flight : the landing case.

5. WINDSHEAR WARNING SYSTEM
THE AEROSPATIALE APPROACH

(Slide 15) WS warning is balanced by comparing longitudinal shear, vertical wind ("SF") properly filtered, actual aircraft energy with minimal aircraft safe energy.

Warning is sensitized by each headwind increase (short period) and desensitized according to the longitudinal mean wind (long period input) avoiding as far as possible the effect of mean turbulence.

The computing principle of AEROSPATIALE Windshear Warning System is as follow (slide 16) ; it could be implemented in digital AFCS.

6. NORMAL PERFORMANCE NUISANCE WARNING

Considering the time of exposure and the nuisance for airlines or air traffic control of frequent undue go around AEROSPATIALE focused its research on landing case, without forgetting the take off case.

In landing case AC 2057A provides us with a simple means of atmosphere modelization allowing the knowledge of wind probability and related turbulence.

Just a problem : the observed wind probabilities don't go further 10^{-3} so we have to continue the model linearly maintaining the turbulence and mean wind relationship.

Results on (slide 17-1-2) allow to define a safe threshold in the world of AC 2057A. The warning threshold can be set at a point guarantizing a level of improbable nuisance warning by landing.

Similar analysis was performed for a fixed threshold (2 to 2,5 kt/s) according to a properly filtered "SF" (slide 17-3).

AC 2057A leads in that case to a nuisance warning level of 10^{-3} to 10^{-4} by approach.

Several piloting technics can also be implemented for decreasing the number of performance nuisance warning. Those technics such as decelerated approach, ground speed mini are not introduced in today's evaluation.

CONCLUSION

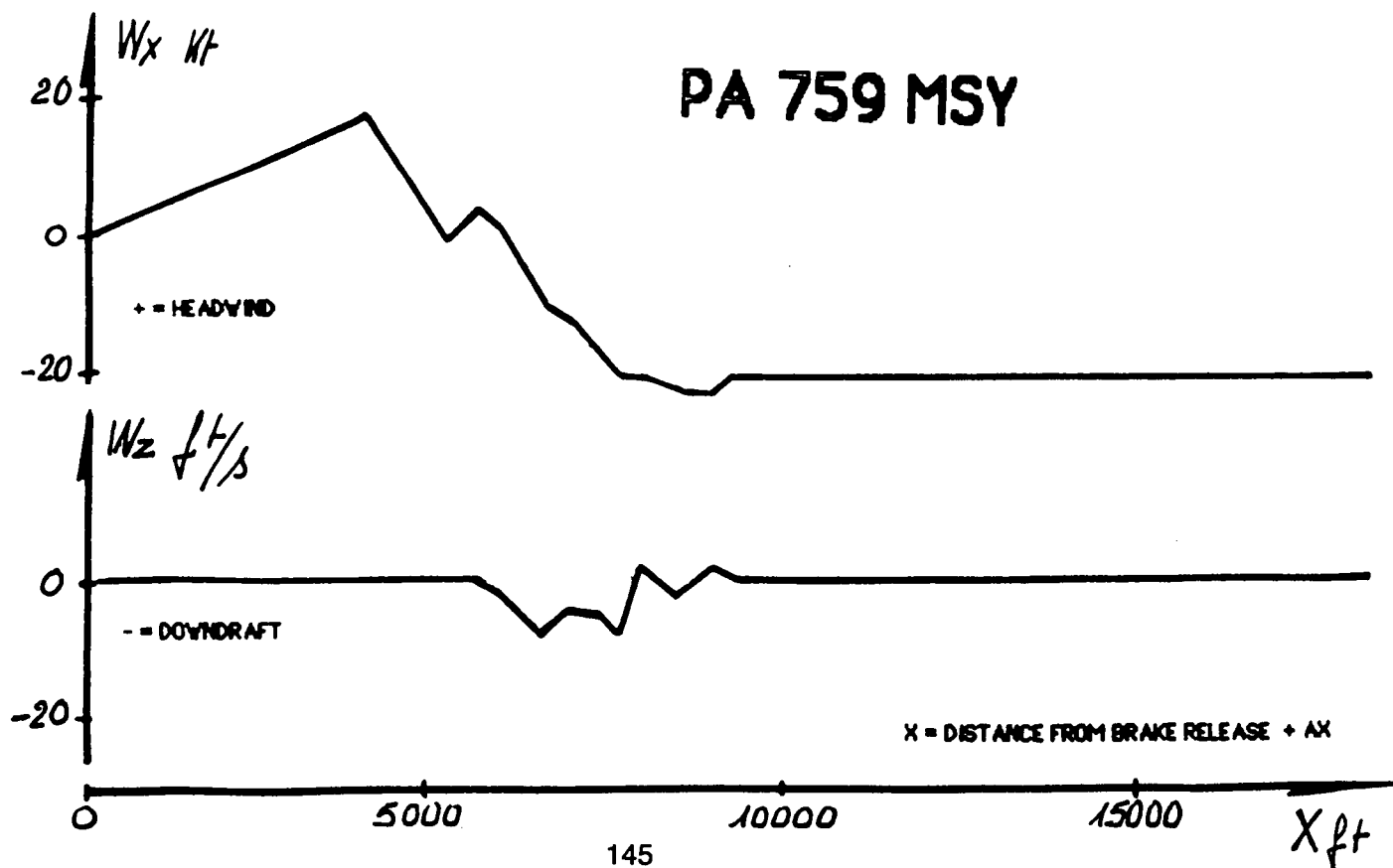
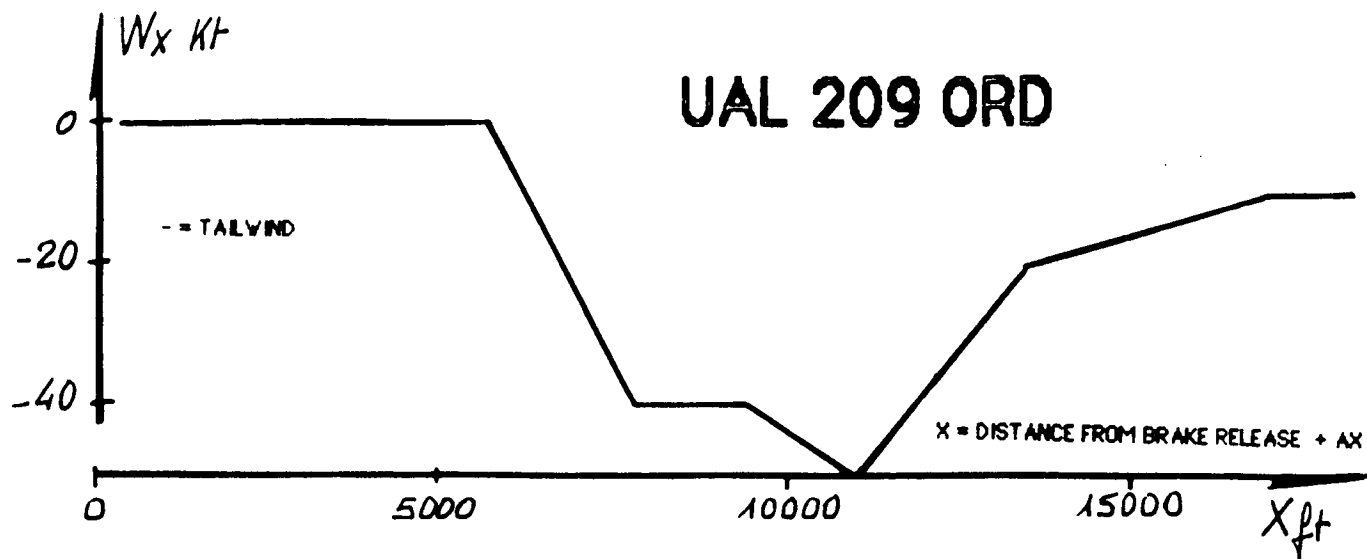
The theme we have here developed is mainly supported by engineers' assumptions considering the lack of reliable statistics.

Nevertheless we have used as far as possible the windshear phenomenon knowledge for detection with sufficient credibility.

LOW ALTITUDE WINDSHEAR

PROBABILITY

- *From NTSB 28 accidents/incidents due to windshear in 1964-1983 period.**
- *About 3000 US AC Performs 5,000,000 take off or landing each year.**
- *Probability of severe low altitude windshear $\approx 10^{-6}$**



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WIND FIELD NR 4

AC 120 41

138 SLOPE

34015 85



HEADWIND WHEN LANDING

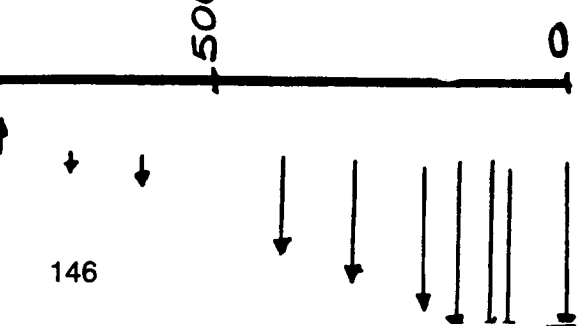
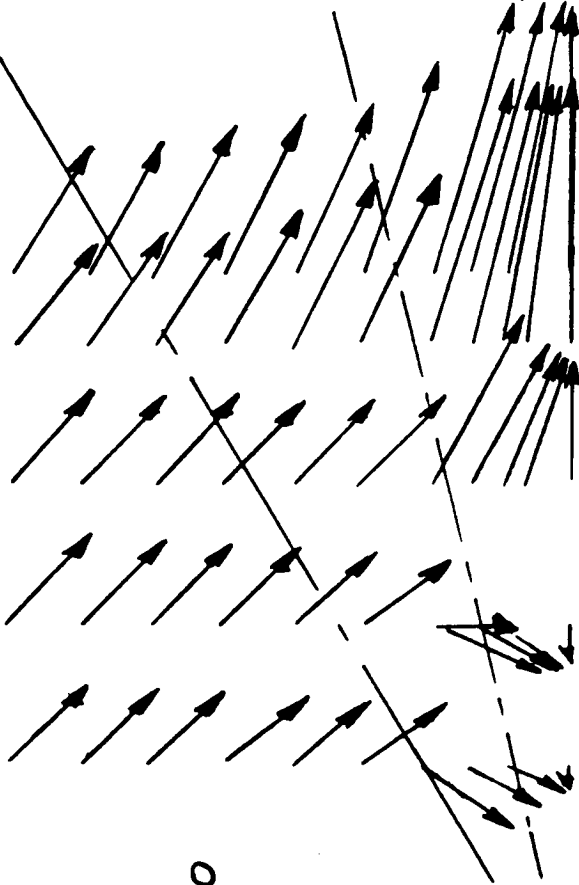
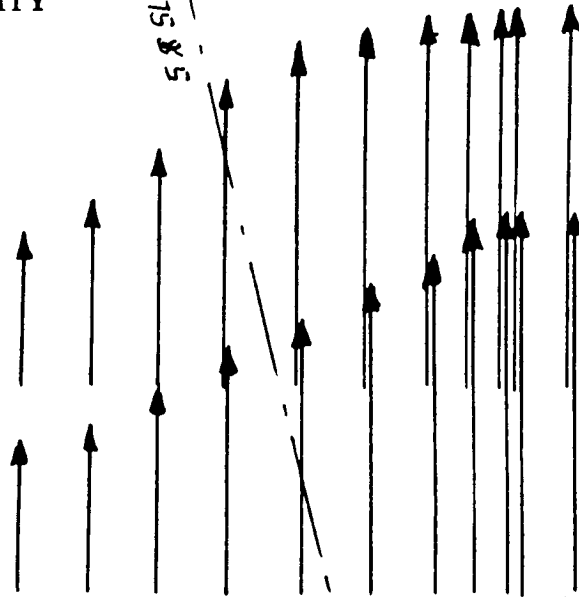


TAILWIND AT TAKE OFF

10KT



DOWNWIND



Z FT

1000

500

RUNWAY

5000

0

X FT

* SHEAR SEVERITY FACTOR

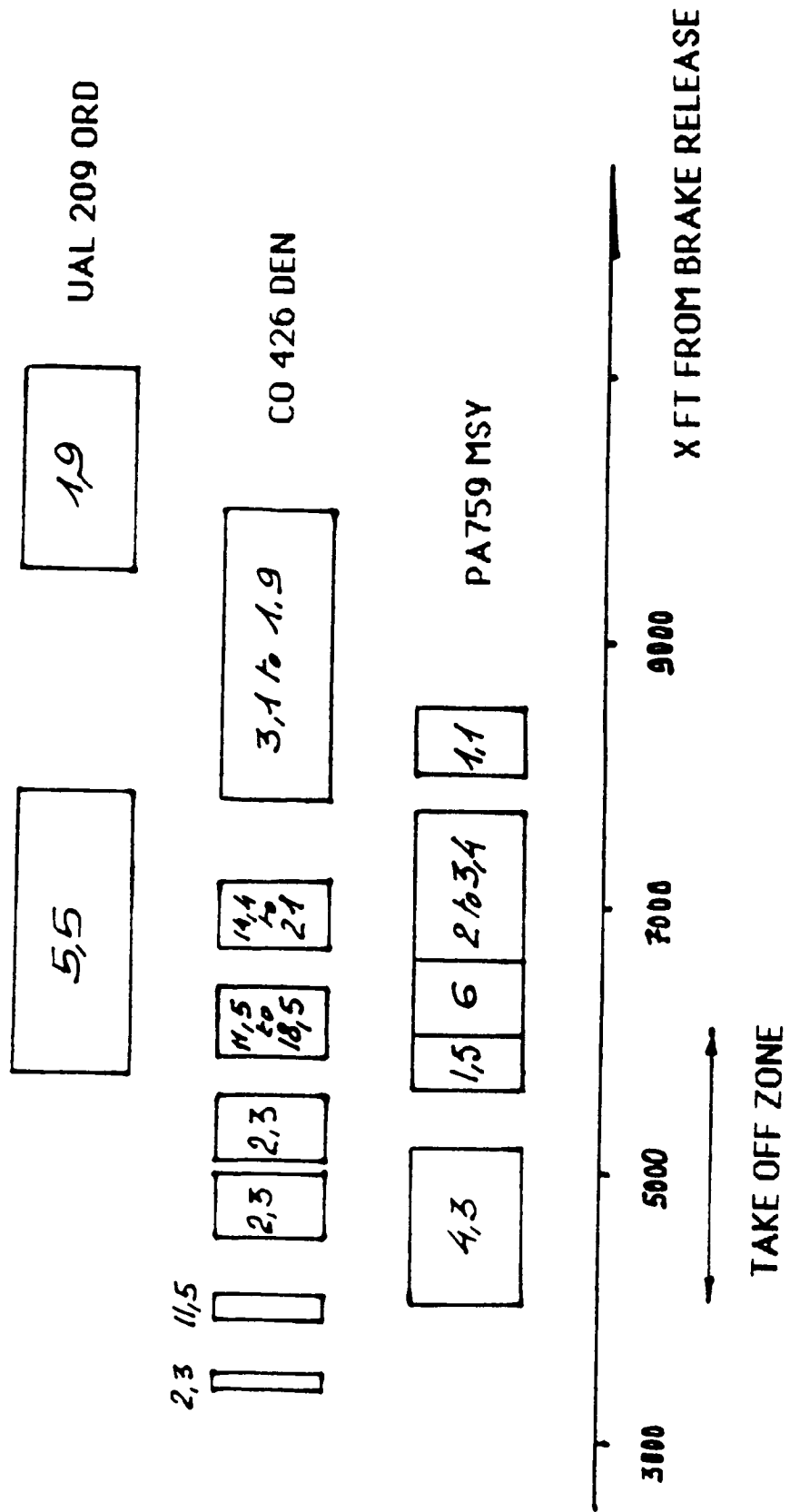
$$dE/dt = M * [c^{te} - V_{x_{air}} * \dot{W}_x + g * W_z]$$

$$SF = [\dot{W}_x - g/V_{x_{air}} * W_z]_{Lim} +$$

headwind < 0 downdraft < 0

SF is in Kt/s

SF IN TAKE OFF CASES



SE IN LANDING CASES

DAL 191 DFW

4	10	1
4	10	7
4	10	2
4	10	6
2	10	4
21	10	17
1,2	10	3,4
4	10	5,7
3	10	4

- 8000

- 10000

-L2000

01041-

X FT TO GPIIP

EA 66 JFK

2

2,2 1

9,9 1,3

16

EA 693 ATL

292

$$\frac{2,3}{8}$$

TWA 524 LGA

$$\frac{2,3}{8}$$

- 2000

-4000

-6009-

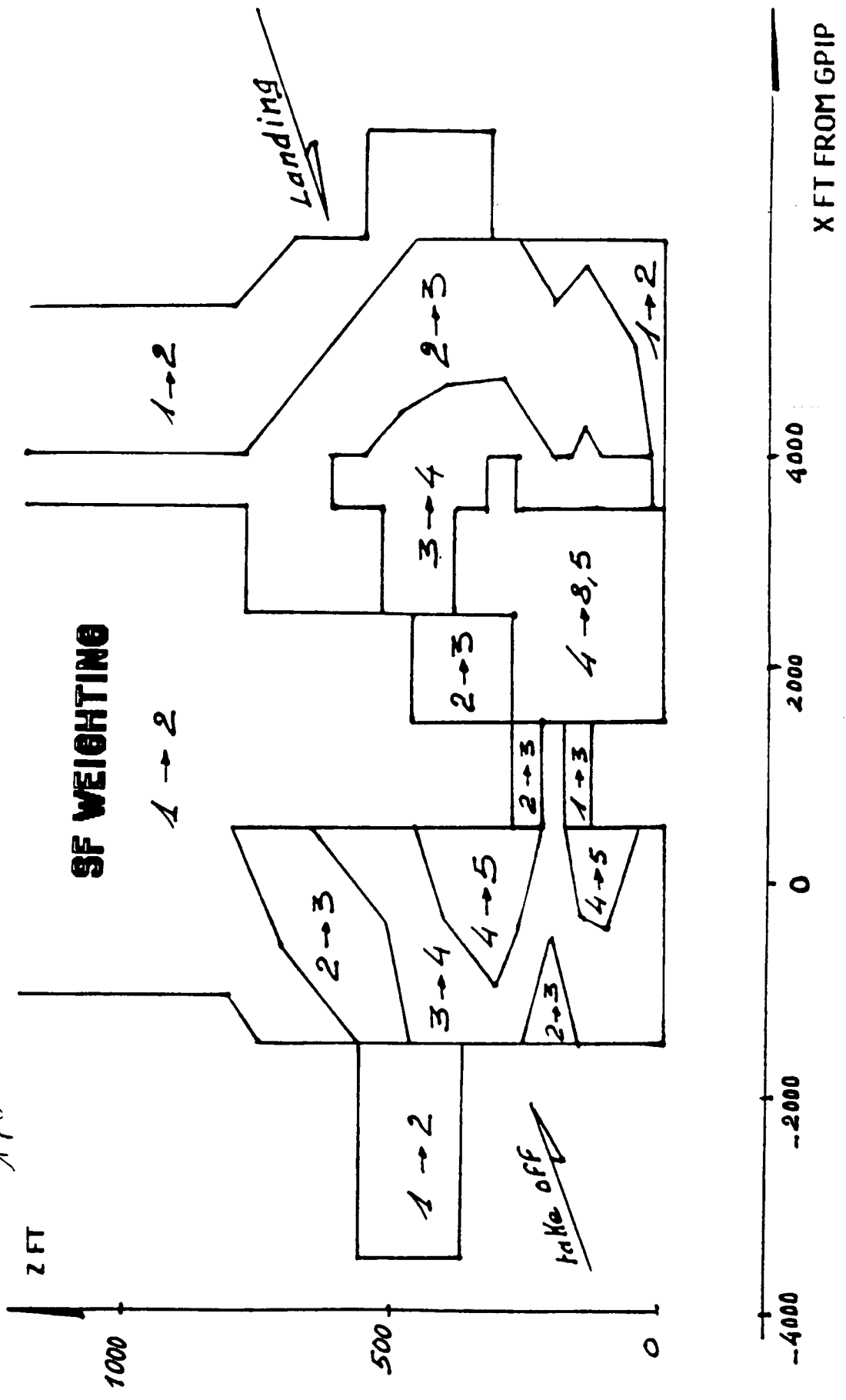
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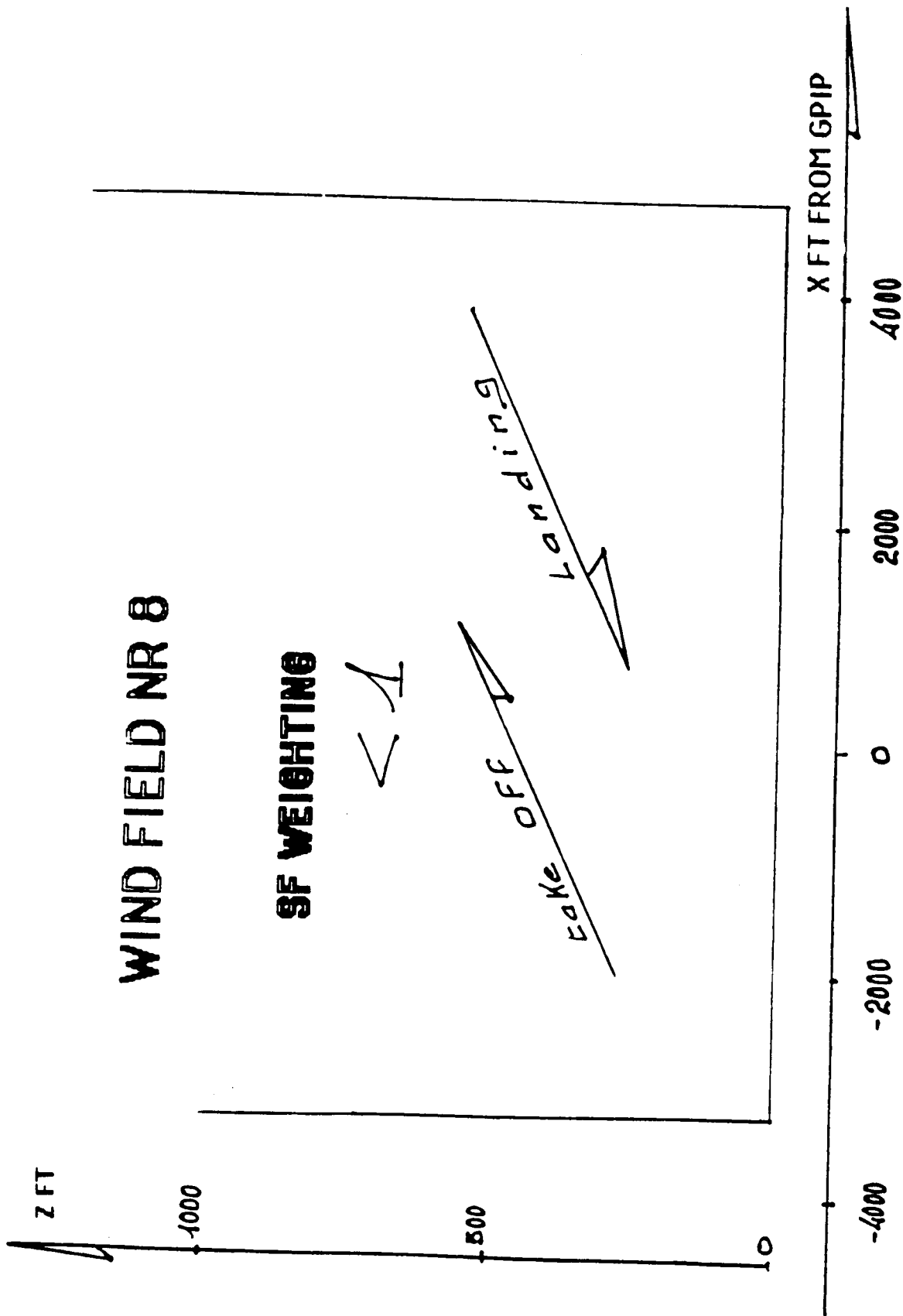
X FT TO GPIIP

GPIB

*Carbide 11
170*

WIND FIELD NR 4





AC 120-41 Wind Fields

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+ more severe

—5275—

 \approx equivalent

10	21	1	+	+	1	+	+
9	1	1	1	1	1	+	1
8	1	1	1	1	1	1	1
7	1	1	1	211	1	21	1
6	+	21	+	21	1	+	21
4	+	21	+	+	1	+	+

WAL 209 ORD
P 210-6

9-01 PD

CO 426 DEN
Dx 10-6

9-01 x d
A/ST

PA 759 MSY
P ≈ 10-6

9-01-10-6

EA 66 JFK
P 2 10-6

9-0170

9-0158
MFD 151 700

9-0178

EA 69 ATL $P > 10^{-6}$

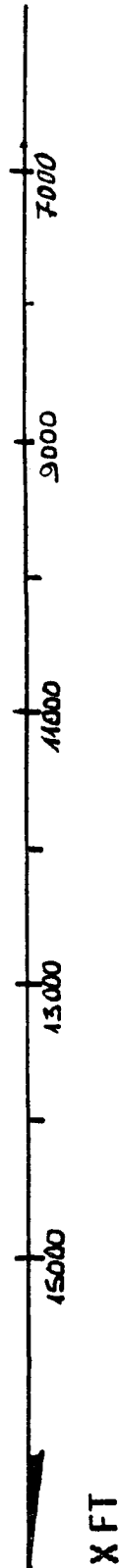
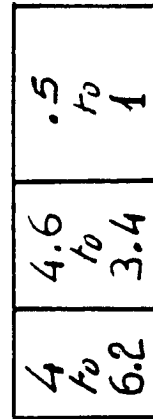
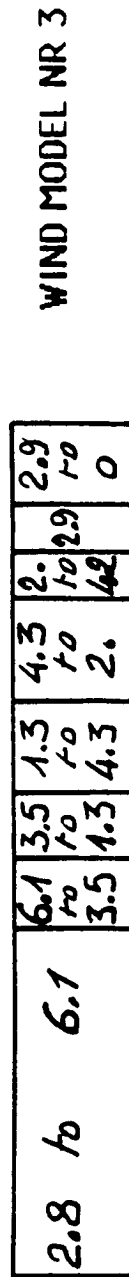
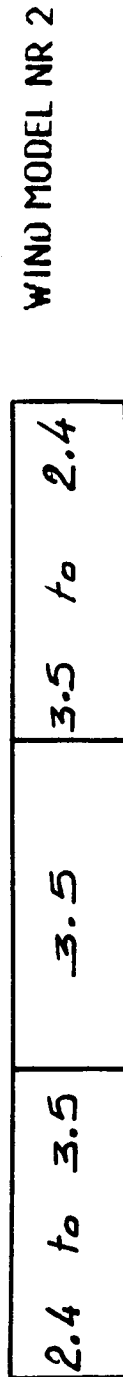
9-01-6

TWA 524 LGA
P-10-6

9-01-6

$$P(W.F)?$$

SF IN WINDSHEAR TRAINING AID



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WINDSHEAR TRAINING AID

AC 120-41

	WM 1	WM 2	WM 3	WM 4
UAL 209 ORD 10^{-6}	\approx	+	+	
CO 426 DEN 10^{-6}	-	-	-	
PA 759 MSY 10^{-6}	\approx	+	+	
EA 66 JFK 10^{-6}				+
DAL 191 DFW $<10^{-6}$				-
EA 69 ATL $>10^{-6}$				+
TWA 524 LGA 10^{-6}				+
Wind Field Nr 4 10^{-6}	-	-	-	+
" Nr 6 10^{-6}	-	\approx	-	+
" Nr 7 $>10^{-6}$	+	+	+	+
" Nr 8 $>10^{-6}$	+	+	+	+
" Nr 9 $>10^{-6}$	+	+	+	+
" Nr 10 10^{-6}	-	-	-	-

+ more severe - less severe

$$WSF = \int_{X_{start}}^{X_{stop}} SF dx \quad \text{in } \frac{Kt}{s} \times ft$$

$$PSF = \frac{WSF}{|X_{stop} - X_{start}|} \quad \text{in } \frac{Kt}{s}$$

Windshear training aid	UAL 209 ORD	14000	2.7
	CO 426 DEN	25000	4
	PA 759 MSY	12000	2.7
	Wind Model Nr 1	12000	2.8
	Wind Model Nr 2	22000	3.1
	Wind Model Nr 3	22000	3.5
	Wind Model Nr 4	27000	3.7
	DAL 191 DFW	32000	4.1
	EA 66 JFK	7000	3.8
	EA 693 ATL	8000	1.6
AC 120.41	TWA 524 LGA	9000	4.2
	Wind Field Nr 4	28000 32000	3.2 3.8
	Wind Field Nr 6	24000 27000	4 4.5
	Wind Field Nr 10	26000 28000	4.3 4.6

in windshear training aid wind models $KW = 1$.

take off speed = 170 Kt Landing speed = 135 Kt

WS Warning System Targets

Performance

- Detect 10^{-6} or $< 10^{-6}$ cases
- If no detection show the good behaviour of the aircraft

Nuisances

- Warning due to Active Failure
AC 25 XX
- Lack of Warning due to Latent Failure
AC 25 XX
- due to performance
 10^{-6} (Landing case)

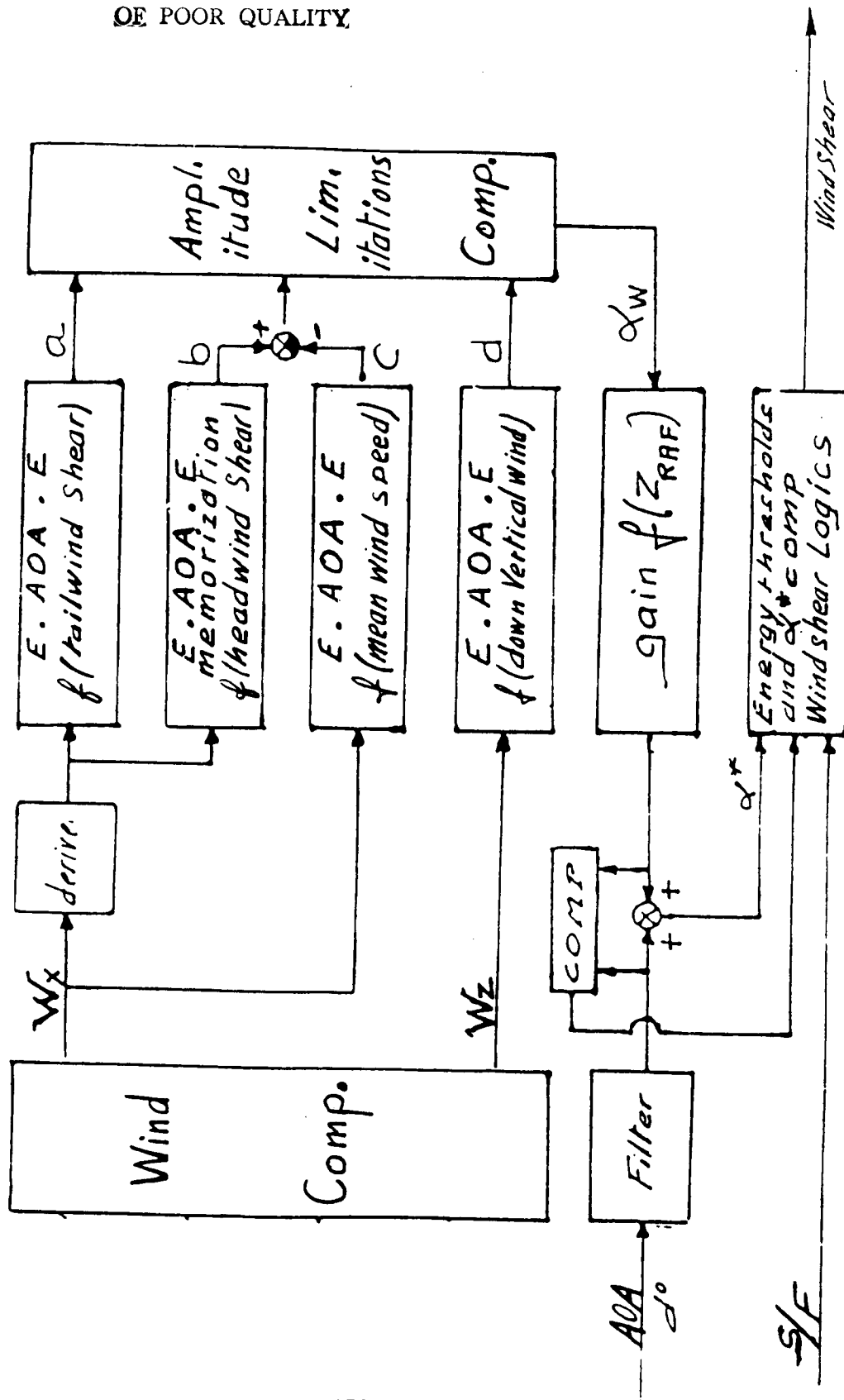
Wind Shear Warning

The Aerospatiale Approach

- Compare shear and vertical wind intensity with AC energy and safe minimal energy
- Sensitize energy thresholds when short period head wind increases
- Desensitize energy thresholds in constant wind if thresholds are sensitized
- Means angle of attack (measured or estimated (V , Weight, CL_{α} , N_z ...)) ground speed, true air speed, vertical speed, pitch attitude, f/s position, altitude

PATENT PENDING

$E^{\circ} AOA^{\circ} E = \text{EQUIVALENT AOA ESTIMATE}$



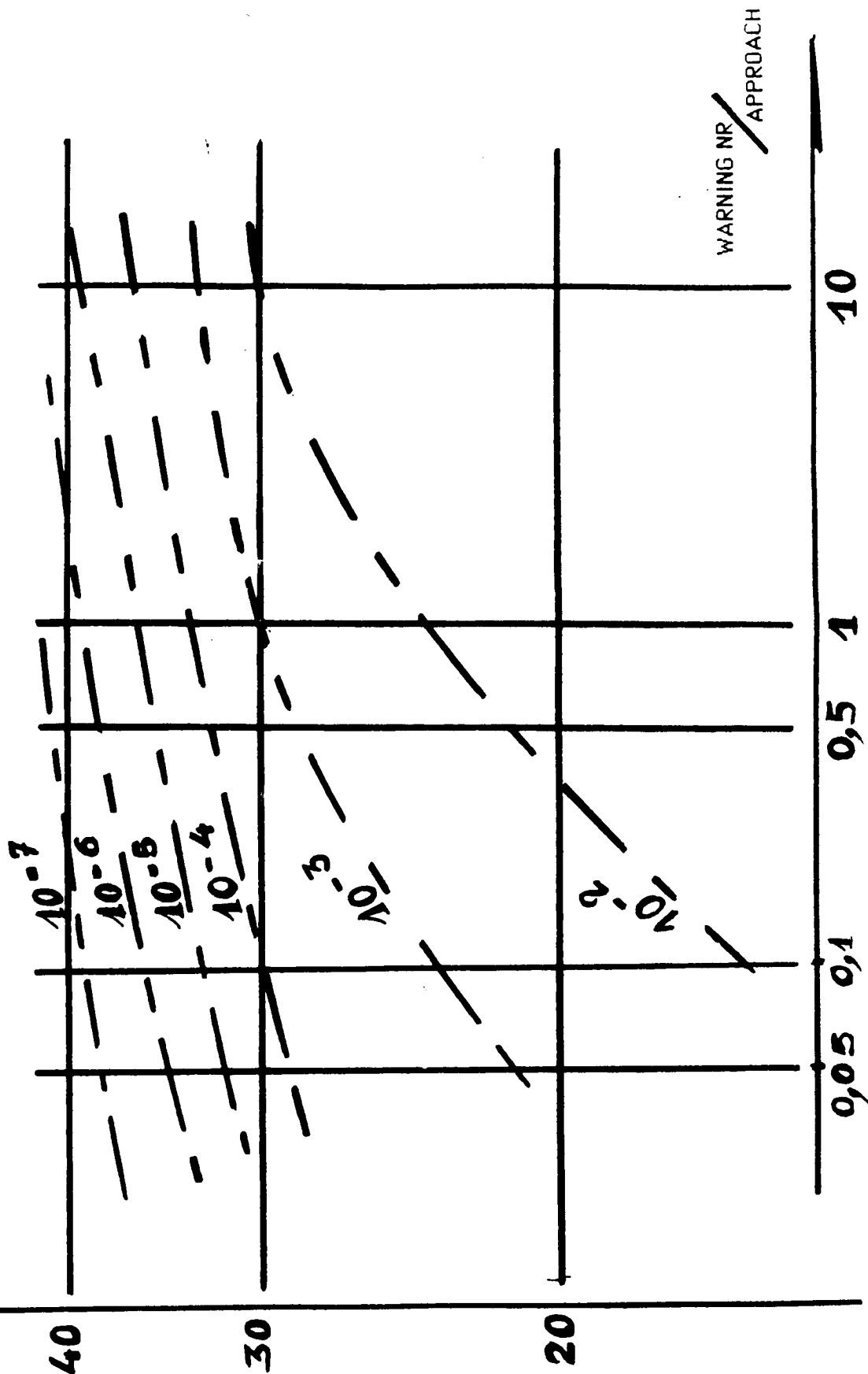
PATENT PENDING

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AEROSPATIALE WINSHEAR WARNING COMPUTATION PRINCIPLE

NUISANCE GRID IN AC 20 57 A

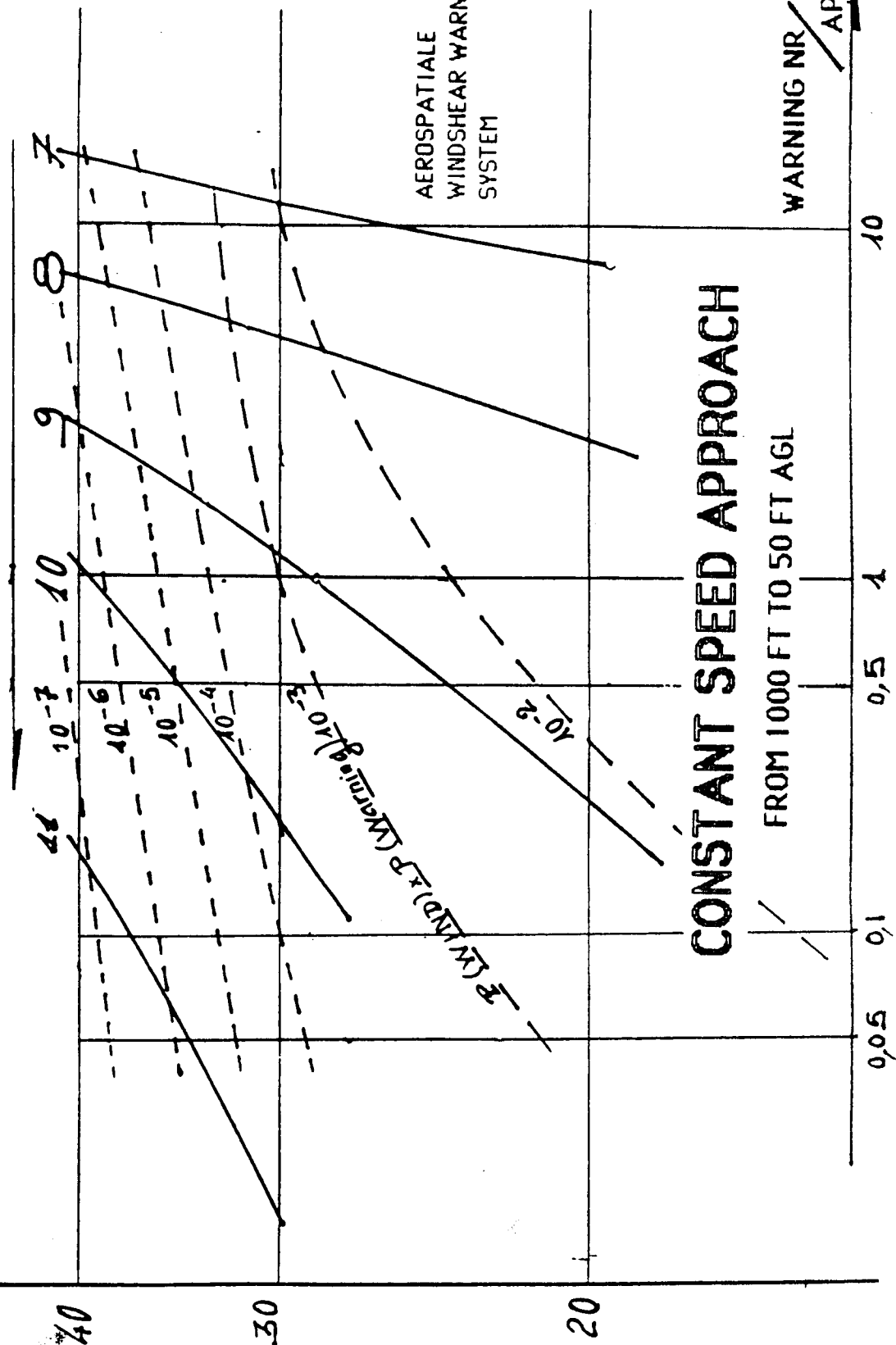
TOWER MEAN
WIND KT

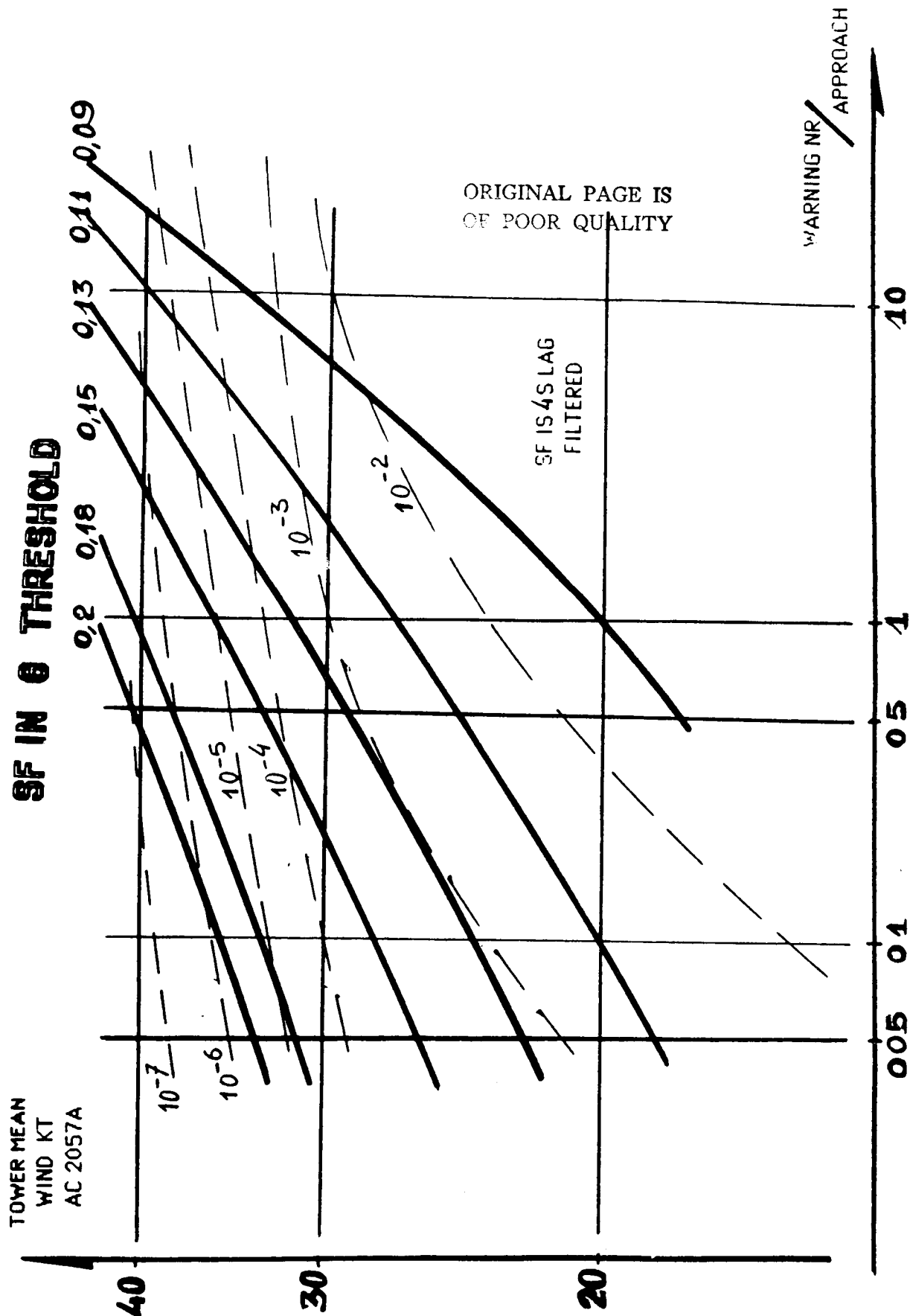


NUISANCE WARNING IN LANDING CASE

TOWER MEAN
WIND KT
AC 20 57 A

WARNING THRESHOLD





QUESTIONS AND ANSWERS

KIOUMARS NAJMABADI (Boeing) - I would like to know if the alert criteria is based on energy rate of change or is it based on energy margin?

J.L. BONAFE (Aerospatiale) - Both. Just a moment. [Pointing to viewgraph] The minimal energy is defined by the threshold you have here. That is right. But, you increase your energy taking your angle of attack, considering the derivative of the horizontal shear, and the vertical shear. So you increase your energy estimate by the shear estimate. You don't compare only the energy threshold and the incidence estimate. It is a, sort of, rate increase in energy. Okay?

KIOUMARS NAJMABADI (Boeing) - So what you are saying is you are estimating your energy loss based on your energy rate of loss and then you are comparing that with your margin, am I correct?

J. L. BONAFE (Aerospatiale) - Yes. This is the way it is implemented.